Technical Paper 251

DEPARTMENT OF THE INTERIOR

JOHN BARTON PAYNE, SECRETARY

BUREAU OF MINES

FREDERICK G. COTTRELL, DIRECTOR

PRINCETON UNIVERSITY
RECEIVED
FEB 26 1921
THE LIBRARY

VENTILATION IN METAL MINES

A PRELIMINARY REPORT

BY

DANIEL HARRINGTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

The Bureau of Mines, in carrying out one of the provisions of its organic act—to disseminate information concerning investigations made—prints a limited free edition of each of its publications.

When this edition is exhausted, copies may be obtained at cost price only through the Superintendent of Documents, Government Printing Office, Washington, D. C.

The Superintendent of Documents *is not an official of the Bureau of Mines.* His is an entirely separate office and he should be addressed:

SUPERINTENDENT OF DOCUMENTS,
Government Printing Office,
Washington, D. C.

The general law under which publications are distributed prohibits the giving of more than one copy of a publication to one person. The price of this publication is 10 cents.

First edition, December, 1920.

Generated on 2024-09-28 18:09 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

CONTENTS.

	Page.
Foreword	5
Introduction	7
Methods—Apparatus used	8
Acknowledgments	10
Elements controlling metal-mine ventilation	10
Conditions affecting temperature of mine air	11
Outside air temperature	11
Rock and water temperature	12
Oxidation of ores and of timber	14
Underground fires	15
Friction of air due to velocity	16
Movement of ground	17
Firing of shots	17
Quantity of air circulating	17
Animal heat and heat from lights and machinery	19
Heated air from adjoining mines	19
Conditions affecting relative humidity of mine air	19
Relative humidity of surface air	19
Moisture content of workings	20
Small fan units and tubing	21
Underground water	23
Conditions affecting composition of mine air	23
Composition of outside air	23
Breathing of men and animals, heat and fumes from miners' lights	24
Oxidation or oxygen absorption by ore and timber	24
Gases from strata and from mine fires	26
Gases from explosives	27
Compressed air	28
Effect of dust on mine air	28
Siliceous dust	28
Dust from soluble oxides or carbonates	29
Arsenical dust and other dusts	30
Influence of velocity on mine air	30
Air velocity in cool mines	30
Velocity at various temperatures	30
Velocity at various humidities	31
Velocity with various gases present	32
Necessity for efficient control of ventilation	33
Methods of providing efficient ventilation for metal mines	35
Including main underground air currents	35
Transmitting main currents through main workings	36
Distribution of air currents to working faces	37
Direction and control of ventilation in metal mines	39
Cost of ventilation of metal mines and saving to be effected	41
Publications on mine gases and mine ventilation	43

Generated on 2024-09-28 18:09 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

VENTILATION IN METAL MINES—A PRELIMINARY REPORT.

By Daniel Harrington.

FOREWORD.

This paper on metal-mine ventilation, by Daniel Harrington, mining engineer of the Bureau of Mines, deals with the second of a series of related investigations in metal mines regarding primarily the health of miners.

In this day, care for the health and morale of miners can no longer be considered as a charitable or even a humanitarian matter, but must be regarded as one affecting the economic situation in the mining industry, for in many cases it determines whether mines can be operated successfully or at all. If miners in poorly ventilated places are able to work only half of their laboring hours by reason of their poor condition or morale, necessarily the cost of production in those places rises, and for most mines the cost of underground work is the chief item in the cost of producing ore. In this brief paper Mr. Harrington has indicated, among other features, how the introduction of good ventilation into the working places has enabled miners to do more work and has thus reduced costs.

The related metal-mining subjects dealing with the health and efficiency of miners, in the order of their being taken up for investigation by the Bureau of Mines, are as follows:

1. The effect of various kinds of mine dust in relation to miners' pulmonary diseases and the preventive measures suggested.

2. The atmosphere in which miners work in metal mines, its contamination from various sources, the effect of different contaminations, the methods of ventilation used and the need of improved ventilation, and the recommendations suggested.

3. Humidity of the atmosphere in metal mines, the effect of high humidity on the health and the working efficiency of miners, and how conditions may be improved.

4. The high temperature found in deep mines and in some comparatively shallow mines, its effect on the health and morale of

Generated on 2024-09-28 18:18 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

workers, and how the temperature may be lowered to proper limits or its ill effects overcome.

This bulletin, although dealing primarily with the second subject, touches upon the other three subjects; in fact, in considering remedies it is practically impossible to investigate one of these subjects without also investigating the others.

Investigation of these problems was begun under the general supervision of the chief mining engineer soon after the establishment of the Bureau of Mines in 1910, Edwin Higgins investigating ventilation and temperatures in iron mines of the Lake Superior District, and H. M. Wolflin investigating similar problems in western metal-mining districts. Mr. Higgins was then assigned to an investigation of dust in mine air, or more specifically, the problem of siliceous dust in the mines of the Joplin district. He worked in association with Dr. Lanza of the Public Health Service, and the reports prepared were published. When Messrs. Wolflin and Higgins were transferred to other work Mr. Harrington was selected to conduct investigations on the related subjects mentioned above, and an intensive investigation was begun in the Butte, Mont., district, in association with Dr. Lanza, and later with Dr. R. R. Sayers, also detailed by the Public Health Service.

Mr. Harrington was deemed peculiarly fitted for the investigation, for although he had experience in metal mines, his most extensive experience had been in coal mining, in which ventilation has always been so vital a matter that the methods are more advanced than in metal mining and indeed form an integral part of the method of laying out coal mines. The plan has been followed in South Africa, where colliery engineers have helped develop the ventilation systems in the deep mines of the Rand. Reports of the investigations at Butte are in press.

More recently investigations of a similar nature have been conducted by Mr. Harrington, assisted by doctors of the United States Public Health Service and engineers of the United States Bureau of Mines, in cooperation with metal-mining companies in Arizona, Idaho, and Utah, with probable extension of the work to mines in Colorado, California, and Nevada.

This paper indicates that valuable information has been obtained on many recognized problems and some new facts have been brought to light. The important facts brought out are as follows:

1. The importance of ground temperature in affecting the temperature of ventilating currents, and vice versa.

2. The production of heat from the oxidation of timber and of sulphide ores.

3. The surprisingly great increase in temperature, from frictional resistance, of high-velocity air passing through high-speed fans and

Generated on 2024-09-28 18:10 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

in pipes and bends, a matter that the bureau proposes to follow up experimentally.

4. The effect of high temperature on the miner, and his sensitiveness to minute quantities of gases when temperatures are high; also, the economic loss to the mining company from the low productivity of miners working in a high temperature.

5. The generally high humidity in mines, and its bad effect.

6. The advantageous effect of cooling the ventilating currents by means of sprays.

7. The importance of ventilating currents of high velocity when temperature and humidity are high, in order to keep down the body temperature of miners.

8. The conclusion, supporting previous investigations, that the wet-bulb temperature is the real index of the conditions that cause discomfort to workers when temperatures are high.

9. The economic loss in the widely prevalent practice of using compressed air rather than special ventilating systems to ventilate working places.

10. The importance in planning operations for a large metal mine of laying out workings, when possible, as is done in coal mines.

11. The importance, for protection from the effects of fires and to control fires, of having large capacity reversible centrifugal fans, the main fans being at the top of shafts where a mine fire can not put them out of commission.

12. The development of a canvas pipe system in headings to permit quick ventilation after blasting.

The Bureau of Mines intends to continue investigations touching on these various points. The investigations already made have received the cordial support of operators and miners in all the various metal mining districts visited by representatives of the bureau. Solutions of the various problems will benefit not only those engaged in metal mining, but those employed in other kinds of mining, and in tunnel work.

GEORGE S. RICE,
Chief Mining Engineer.

INTRODUCTION.

Ventilation in coal mining is as important as any other item of operation and plans for circulating adequate volumes of air must be made at least as soon as actual opening work begins. In metal mining comparatively little forethought is given to ventilation. Many metal-mine operators insist that it is not necessary, or is impracticable for their mines. State laws relative to coal-mine ventilation are generally drastic, for terrible disasters have demon-

Generated on 2024-09-28 18:09 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

strated the necessity of supplying enough air to remove noxious and explosive fumes and gases. Failure of coal operators to establish and maintain ventilation has brought such swift and costly retribution in loss of life and property that no argument is now necessary to convince a coal operator that ventilation is not a mere fad. For metal mining, however, State laws governing ventilation either do not exist or at best are lax and indefinite. In metal mines explosive gases are generally absent; noxious fumes from explosives are usually handled in a haphazard manner by compressed air; and, on the whole, only within recent years have the most eminent metal-mining engineers or operators been able to see any gain to justify the effort or expense of establishing consistent air circulation underground.

Notwithstanding the fact that ventilation is much more an integral part of present-day practice in coal mines than in metal mines, there is actually a greater necessity for efficient control of air circulation in metal mines than in coal mines. Coal mines need the circulation of good air to remove the noxious fumes of explosives and to expel explosive gases from mine workings, but besides these reasons metal mines also need ventilation to remove dusts and gases dangerous to health and to reduce high temperatures and high relative humidity which lower the working efficiency and ultimately undermine the health of underground employees. In coal mines, especially in the United States, high temperatures are rarely encountered and high relative humidity is desirable to prevent explosions of coal dust. Harmful gases, such as arsenical gases, carbon dioxide, and others that issue from the ground in many metal mines, are rare in coal mines. The better health of coal miners as compared with metal miners is probably due to the fact that most coal mines are well ventilated, whereas in metal mines ventilation is ignored or regarded as impracticable or a fad.

METHODS—APPARATUS USED.

The data on which this report is based were obtained, except in a very few instances, by experiments, readings, etc., made or participated in by the author in or around metal mines in Montana, Colorado, Utah, Nevada, Arizona, and Idaho. Most of the observations were made in mines of Butte, Mont., where conditions are probably more varied than in any other metal-mining district in the United States, and where much systematic work is being done in ventilation.

Much information was obtained during dust and ventilation studies made by the author, in association with engineers and doctors of the Bureau of Mines and the United States Public Health Service, in metal mines of Idaho, Montana, and Arizona. Other data were obtained incidentally during visits to various mines by the author, when

Generated on 2024-09-28 18:16 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

making examinations after mine fires or other disasters, and when making visits for general observation.

The anemometers used in obtaining velocities were of the ordinary portable type used in coal-mining practice, and were calibrated from time to time in Washington. All observed air velocities were corrected in accordance with curves obtained by such calibrations. Anemometer readings were generally taken by moving the anemometer through the cross section of the place during a minute's time, several such readings being taken and their average used; when especial accuracy was desired the cross section was divided into six to eight equal divisions, readings of a minute taken at each division, and the whole averaged. Frequently two anemometers were used and the readings checked against each other.

Cross sections of places were measured in the ordinary way with tape, and no attempt was made in places of irregular cross section to obtain extremely accurate results. When possible, however, velocities were taken at places of regular cross section, as at regulators, or at doorways.

Temperatures, both wet and dry bulb, were taken with the Bureau of Mines standard sling psychrometer, and in many instances two such psychrometers, in the hands of different observers, were used to check readings. Relative humidities were obtained from humidity curve charts of the Bureau of Mines and from Marvin's psychrometer tables.

For barometric readings aneroid barometers of standard make were used, being held with the face horizontal and ample time given to settle. Changes of pressure were taken at doors, etc., not only with the barometer, but also with portable water gages, and in general the barometer readings checked readily to one-quarter inch of water-gage reading.

Samples were taken of intake surface air, and of the return air of the mine, and of air from various splits; air samples (frequently in duplicate) were also taken in working places at faces of raises, drifts, crosscuts, and stopes, generally of air supposed to be abnormal, but frequently of air supposed to be normal. These samples were gathered by breaking, at the place to be sampled, the tip of evacuated tubes of the general shape and size of the bulb of a 16-candlepower incandescent light. The tube, after taking the air sample, was sealed with an especially prepared wax. Such samples contained about 250 to 300 c. c. They were analyzed at the Pittsburgh, Pa., laboratory of the Bureau of Mines, A. C. Fieldner, supervising chemist, for CO_2, O_2, CO, CH_4, and nitrogen plus other constituents. For specific samples, such as mine-fire fumes, explosives fumes, etc., determinations were made as SO_2, H, and oxides of nitrogen.

Generated on 2024-09-28 18:06 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

Rock temperatures were ascertained generally by inserting the psychrometer into drill holes, care being taken to eliminate as far as possible such extraneous influences as heat from dry drilling, cooling from water in wet drilling, or cooling by radiation. After the thermometer (psychrometer) was inserted into the drill hole and forced as far as possible toward the end of the hole, the collar of the hole was closed with clay, or if that was not obtainable, with a cloth, such as a handkerchief, and the thermometer was allowed to remain until its reading was constant. Water temperatures were obtained by placing the mercury bulb of a psychrometer in the water.

ACKNOWLEDGMENTS.

Various mining companies in the west gave cordial cooperation in the work of obtaining data, many of them supplying a man for weeks at a time to accompany the investigators underground. In addition many data as to costs, labor performance, fan performance, etc., were freely supplied, and men and equipment were furnished in the performance of suggested experiments. Many of the underground data were obtained in cooperation with Dr. Lanza and Dr. Sayers of the United States Public Health Service, as well as with Mr. Rice, chief mining engineer of the Bureau of Mines, and Engineers Allen, Dyer, Forbes, McElroy, and Gardner, of the Bureau of Mines. Pertinent suggestions as to methods to be used in starting the work, and helpful criticisms of the manuscript were made by Mr. Rice. Air samples in considerable number were analyzed by the chemists, A. C. Fieldner in charge, at the Pittsburgh laboratory of the bureau. To all of the above men grateful acknowledgment is made.

ELEMENTS CONTROLLING METAL-MINE VENTILATION.

The main influences that affect metal-mine ventilation are temperature, humidity, noxious gases, dusts, and the movement of the air.

The conditions affecting the temperature of mine air may be classified as follows:

1. Outside air temperature.
2. Rock and water temperatures underground.
3. Oxidation of ores and timber.
4. Mine fires.
5. Friction of air through workings.
6. Movement of ground.
7. Firing of shots.
8. Quantity of air circulating.
9. Heat from lights and breathing of animals.
10. Heat from electric motors and other machinery.
11. Heated air from other mines.

Generated on 2024-09-28 18:07 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

The conditions affecting the relative humidity of mine air are as follows:

1. Relative humidity of outside air.
2. Moisture content of shafts and other workings.
3. Effect of various air quantities, velocities, and temperatures.
4. Effect of small fan units with galvanized iron or canvas tubing.
5. Underground water.

The composition of the atmosphere in metal mines is affected by these factors:

1. Composition of outside air.
2. Breathing of men and other animals.
3. Lights used by miners.
4. Oxidation, or absorption of ogygen, by timber and ore.
5. Gases from the mine strata and from mine fires.
6. Gases from explosives.
7. Gases from compressed air.

The injurious dusts that may be in mine air are as follows:

1. Siliceous dust.
2. Dust from lead carbonates.
3. Arsenical and other poisonous dusts.

The following factors are to be regarded in considering the velocity of ventilating currents:

1. Advisable air velocity in cool mines.
2. Effects of moving air at various temperatures.
3. Effects of moving air at various humidities.
4. Effects of moving air containing certain gases.

CONDITIONS AFFECTING TEMPERATURE OF MINE AIR.

OUTSIDE AIR TEMPERATURE.

The temperature of the outside air has a pronounced effect, at least in the vicinity of the shaft, on the temperature of mines of less than 1,000-feet depth and those dependent on natural ventilation. Underground air in shallow mines is likely to be cold in winter and warm in summer, especially if air velocities are 500 linear feet a minute or more. In mines having natural ventilation—that is, no machinery to control or induce air flow—the air velocity will generally be high when the temperature of the outside air differs greatly from that of the underground rock and water. In mines over 1,000-feet deep, in which the temperature is usually 80° F. or more, the air velocity will be high in winter and low in summer, especially at midday; in the fall and spring, with cool nights and hot days, there will

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

be daily reversal of air currents with intervening periods when the air does not flow.

In mines 2,000 feet or more deep, especially those having mechanical ventilation hour to hour or day to day, variations of surface-air temperature have little influence on general air temperatures underground, although such variations will increase or decrease the amount of power required to maintain in circulation a constant volume of air. In a deep shaft acting as downcast, with air velocity of about 800 linear feet a minute and total volume of about 50,000 cubic feet a minute, all delivered to points below the 2,000-foot level, a series of readings over an entire winter gave an average of 52.7° F. at the 2,000-foot level in the downcasting air. No reading varied over 2° F. from that average, although temperature readings at the surface varied by 24°. In the same shaft summer readings at the 2,000-foot level varied only a fraction over 1° F. from the summer average of 64.8°, although outside air temperatures varied 33° F. As indicated above, there was a seasonal air-temperature variation from the winter average of 52.7° to the summer average of 64.8° F. at the 2,000-foot level in this shaft, yet the mean temperature of the surface air varied from 32° F. in winter to 76.8° F. in summer. At underground points 1,000 feet from this shaft in main air courses, when velocities were 200 to 500 linear feet a minute, fans being worked 24 hours a day, no variation of temperature was noticeable summer or winter, day or night. In downcast shafts 500 feet or more deep and with considerable quantities of falling water air temperatures at foot of shaft will generally take essentially the temperature of the water, a fact which should be taken advantage of in reducing entering air temperatures.

ROCK AND WATER TEMPERATURES.

Temperature of underground rock undoubtedly influences mine-air temperatures much more than does that of surface air; on the other hand, circulating air has a well-defined effect on rock temperatures. The data above given as to constancy of intake-air temperature at the 2,000-foot level of a downcast shaft shows the effect of rock temperature on comparatively large volumes of swiftly moving air. This influence of rock temperature on air temperature is especially great when the difference in initial temperatures is marked. When outside temperature was 14° F. in the shaft mentioned, air temperature increased 3.43° per 100 feet of travel in the shaft from the surface to the 700-foot level, where rock temperatures were about 65°; from the 700-foot level to the 2,000-foot level the increase was at the rate of about 1.1° F. per 100 feet, the rock temperature at the 2,000-foot level being above 80°. These decided increases in tem-

Generated on 2024-09-28 18:18 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

perature took place with a volume of air over 50,000 cubic feet a minute, flowing at rate of about 800 linear feet a minute. Similarly, in drifts and crosscuts, with air velocity 200 to 500 linear feet a minute, temperature changes at the rate of approximately 1° F. for each 100 feet of travel until air temperature and rock temperature equalize. In underground places, with stagnant air or with very sluggish movement of air, air and rock temperatures rarely differ more than 1° or 2°. This is important in metal mines, where the air at nearly all working faces is stagnant or sluggish. However, where a considerable quantity of water drips from above, temperature of the mine air quickly equals that of the water drippers, irrespective of the rock temperature.

Although rock temperature quickly affects air temperature, circulating air currents tend to equalize the two. For instance, the original rock temperature at the 3,000-foot station of a downcast shaft was 91°; after approximately 30,000 cubic feet of air a minute, at about 67° F., had passed this point continuously for about five years, the rock temperature, as determined at the bottom of a standing drill hole, had fallen to 69½° F. Hence, if considerable quantities of air are circulated fairly rapidly through a region of hot rock, the rock temperature can be gradually cooled and will in turn help to keep down the temperature of the air currents. This was exemplified in a mine where a fire of long standing had heated the rock for long distances from the fire. By directing a current of swiftly moving air at 90° F. against this rock the temperature of the place was reduced from 152° F. to approximately 130° in a few weeks, and then the rock temperature was still falling. In another mine the rock temperature of a crosscut was reduced from 94° to 78° in about four years by coursing approximately 14,000 cubic feet of air a minute with initial temperature around 60°, velocity of 400 linear feet a minute, the air temperature increasing about 1.2° F. per 100 feet of travel through the crosscut.

Underground water may also greatly influence underground air temperatures. Running water on the floor of drifts or stopes scarcely affects air temperature unless the temperature of the water is markedly different from that of the surrounding air; but falling water, whether in large quantities, as in a shaft, or in smaller quantities, as in "drippers" from roof or back of a crosscut, drift, or stope, does have a determining influence. In a shaft falling water will quickly give to air in the shaft essentially the temperature of the water. Comparatively small amounts of water dropping from a roof or back through the air, either stagnant or in motion, quickly gives to the air essentially the temperature of the water even when the water temperature differs decidedly from that of surrounding rock. Much of the excessive temperature and humidity of stagnant

Generated on 2024-09-28 18:06 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

air at blind ends could be avoided if warm drippers were caught and conducted to the floor without dropping through the air.

Cool water (temperatures 65° F. or less) can readily be had even in deep, hot mines by piping surface water underground and using it to reduce air temperatures. In a hot mine, with large volume of air at 104° F., four small sprays of water at 50° F. in 140 linear feet of drift reduced the air temperature to 99° F., and in this experiment the sprays were not made efficiently or placed most effectively. In a downcast shaft water drippers had a temperature of approximately 50° F., and 15,000 cubic feet of downcast air a minute reached the 1,200-foot level at 50° F. even when the temperature of the surface air was over 90° F.

Usually, but not always, rock and water temperatures are approximately the same at the same underground horizon. Rock temperatures may be greater or less than the temperature of water issuing from the rock. Moreover, the temperatures of different kinds of rock in the same mine and at the same depth may differ considerably; in many places the temperature of vein matter differs several degrees from that of the surrounding walls, and the temperature of one kind of vein matter may differ appreciably from temperature of another kind of vein matter at the same horizon and less than 100 feet away.

OXIDATION OF ORES AND OF TIMBER.

Although the oxidation of ores and of timber increases temperature in mines, the exact amount of the increase is difficult to determine. Lead or zinc sulphide ores seldom fire. Iron or copper sulphides or carbonaceous shales occasionally found in metal mines do not fire spontaneously or burn very freely unless they are in a finely divided state; hence ore in place is not likely to fire unless subjected to heavy pressure which breaks or crushes it, causing fines and chimneys.

Oxidation of timber, however, is almost universal underground and in mines where much timber is left in abandoned places this timber is almost certain to decay or oxidize. The rapidity of this action determines the amount of heat liberated, and oxidation is greatly accelerated when the timber is crushed by heavy weight and the air circulation in the surrounding region is sluggish. Temperatures well over 100° F. are readily found in the air issuing from crushed, decaying timber, whether in back-filled stopes or in timber matte overhead, although the natural rock temperatures are 30°, 40°, or more lower. Frequently this occurs in mines where the ore has no combustible or oxidizable constituent, and timber oxidation alone is responsible for the increased temperature.

Although oxidation of ore and timber is promoted by sluggish air currents and can be absolutely prevented by sealing tightly from air,

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

oxidation takes place also in moving air currents. In a Butte mine, in a long, damp crosscut in granite, partly timbered, the rock temperature and the temperature of water flowing on the floor being 61½°, the temperature of 6,000 cubic feet of air flowing at about 200 linear feet a minute rose from an initial temperature of 61½° to 76° at the end of the crosscut, which was 4,400 feet long, this increase of 14½° F. in 4,400 feet being about 0.3° for each 100 feet of travel. As rock and water temperatures were the same as the initial air temperature, none of the increase could be ascribed to rock or water, nor could the increase, because of the relatively low velocity, be caused by friction. Oxidation of timber, possibly aided slightly by alteration of the pyrite in the granite, must have caused the temperature increase.

Where large quantities of crushed, decaying timber are in close proximity to underground working places, if air is not in circulation, the air temperature is affected far more by timber oxidation than by rock or water temperature or by any other cause except, possibly, air movement. Thus the use of large amounts of timber in metal mining necessitates providing and maintaining good circulation of air.

UNDERGROUND FIRES.

Mine fires that are extinguished within a few days, weeks, or even months have comparatively little permanent effect on underground temperatures, but fires that burn year after year have a decided influence, whether they are in timbered back-filled stopes comparatively tight, abandoned, and with only 10 to 15 per cent of combustible matter available, or in high sulphide, heavily timbered, more or less open stopes with 40 per cent or more combustible matter. An indirect effect of such fires is to handicap or completely interrupt the normal ventilation established, such interruption frequently being caused by fear of inducing air movement that may supply oxygen to feed the fire. Sometimes it is necessary to tunnel through a burning area to extract ore from another deposit beyond; then all air passing through the tunnels is heated. In mines where fires have been burning long, rock may be highly heated for long distances from the seat of the fire and greatly increase air temperatures in adjacent workings. In order to prevent the heated and vitiated air from the fire region from passing to the cooler parts of a mine, some mines have adopted a system of pressure ventilation in which air holds the gases within the fire region and probably a small amount of air is forced into the fire area rather than being taken from it.

Mines having more or less permanent fires are generally well ventilated, yet are likely to have higher temperatures than similar mines free from fires. Frequently temperature could be lowered, at least in regions distant from the fire, if an efficient system of air splitting

Generated on 2024-09-28 18:09 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

were established with the mine-fire region on separate split from other workings.

FRICTION OF AIR DUE TO VELOCITY.

Although friction due to velocity undoubtedly increases underground air temperature, the exact amount of this in open drifts and shafts is difficult to determine separately from the influence of rock and water temperatures and of oxidation. Air velocities in metal mines seldom exceed 1,000 linear feet a minute, and though cross-sectional area is frequently small the friction is not very great. Where velocities are higher than 1,000 linear feet, although the exact amount of temperature increase due to friction in open workings is difficult to determine, yet it can be done definitely when a small fan and metal or canvas tubing is used to convey air, especially if the lengths of tubing are less than 500 feet.

In a 300-foot length of 10-inch dry canvas tubing, fan-forced air with initial temperature of 71° F. emerged at a rate of 4,800 linear feet a minute at a temperature of 77½°, a total increase of 6½° or 2.17° for 100 feet of travel, a remarkable amount of temperature increase, as the air was within the tubing but 1¼ seconds. In another test air with an initial temperature of 72½° F. was forced at a velocity of slightly over 4,000 linear feet a minute through 300 linear feet of 16-inch dry canvas tubing, and emerged with temperature of 79° F., the increase again being 2.17° for 100 feet of travel. The tubing in both tests had no abrupt turns, although it was by no means straight; it was suspended in the air by wire supports, and hence was not in contact with hot rock. Initial air temperature was taken at the fan intake, so the heating effect of the motor attached to the fan may have been a factor as well as the heat developed by functional resistance of the air as it passed through the fan.

In another experiment air with an initial temperature of 71½° F. was forced through 60 feet of 16-inch galvanized-iron pipe with two 45-degree elbows and one 90-degree elbow; the velocity was about 6,000 linear feet a minute and the air emerged at 78½° F., an increase of 11⅔° F. for 100 feet of pipe. In a similar experiment with 16-inch canvas pipe, air with initial temperature of 79° F. emerged from the end of 95 feet of dry pipe with one 90-degree and two 45-degree elbows at the rate of 6,700 linear feet a minute and a temperature of 84° F., or at rate of 5½° F. increase for 100 linear feet of travel against 11⅔° for galvanized-iron pipe. In the 16-inch canvas pipe experiment, when a spray of water at 67° F. was introduced into the intake, the amount of water used being about 100 gallons every 8 hours, temperature of air between intake and delivery ends of the pipe practically did not increase. This shows a simple method

Generated on 2024-09-28 18:07 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

of controlling such increases of temperature. The effect of wet pipe and water drippers was shown when air at 82° F. was forced at a velocity of 4,200 linear feet a minute through 2,200 linear feet of 16-inch canvas tubing, and emerged at a temperature of 79½° F. The 2½° decrease in temperature was due to the fact that water at temperature of 72° to 75° F. dripped upon the pipe for much of its length. Undoubtedly, much of the increase in temperature was caused by the friction within the fan plus the heat from the motor transmitted through the fan casing.

MOVEMENT OF GROUND.

The effect of the movement of large masses of ground on underground temperatures is decided but not readily measurable. Fault veins usually have higher rock temperature than those in which no frictional movement has taken place. The influence of moving ground on spontaneous firing in deposits of high sulphide ores and deposits of carbonaceous matter has been mentioned (p. 14). The total heating effect of the movement of immense volumes of ground in the caving system, and on wide stopes in highly inclined veins, although important, can only be estimated and can not be separated from the effect of subsequent oxidation of crushed timber and ore.

FIRING OF SHOTS.

In general, the amount of heat liberated by firing approximately one-half pound of dynamite per ton of ore extracted, although considerable, does not seriously affect temperatures in large open stopes or in any place where the air currents have good velocity. On the other hand, in confined poorly ventilated places in raises, drifts, and crosscuts where four or more pounds of dynamite may be used to a ton of ore, the local increase in temperature is considerable. In a 5 by 7 foot crosscut in granite a charge of 14 holes with 70 pounds of 40 per cent gelatine dynamite was fired, raising the air temperature at the face from 83½° F. before firing to 98° F. about three minutes after firing. Although this case is abnormal, it illustrates the influence of the firing of explosives on local air temperatures in confined places.

QUANTITY OF AIR CIRCULATING.

Inasmuch as air coursing at 300 to 400 linear feet a minute, which is the average main air course velocity in many metal mines, is cooled or warmed about 1° for each 100 feet of travel until its temperature is that of the rock, in mines where the rock temperature

Generated on 2024-09-28 18:06 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

is high the air temperature will increase 10° for 1,000 feet of travel in main air courses, and at a much higher rate for slower velocities in more open workings. In the shaft metal mines of the West it is difficult to get air to the 2,000-foot depth at a temperature less than 60° F., irrespective of surface temperature or of intake air velocity; hence, by the time the air has gone 2,000 feet from the intake shaft, its temperature will have reached 80° F. if the rock temperature is 80° or more and, in general, workings below the 2,000-foot level will have rock temperature above 80°. Although 80° F. is not the maximum temperature at which efficient work can be done, yet at 80° F., or over, other conditions, such as humidity, purity of air, and velocity, must be so nearly the best in order to insure effective work from miners that 80° wet bulb should be the upper limit of underground air temperature. Hence, air flow underground should be so arranged that the velocity is about 400 linear feet a minute, or more, and a maximum length of travel between the point of leaving intake air course and the last user is about 2,000 feet. With a cross section of 35 square feet, that of the average underground haulage way for the ordinary ore car, the total quantity of air in a split with a velocity of 400 linear feet a minute would be 14,000 square feet, and with workings 2,000 feet from the intake air course there should be one split for each such set of workings; hence, the total quantity of air needed would be that for the total number of splits at 14,000 cubic feet each a minute. If mine-air splitting of some nature, similar to that above outlined, were put in effect in hot mines so as to deliver air to the return air courses when it reached a temperature of 80°, the cool air currents would quickly decrease rock temperatures and automatically permit decreasing the necessary quantity of air. Present-day practice of causing air, after it has attained a high temperature, to course more or less at will through various workings, merely perpetuates high rock temperatures, high air temperatures, and inefficiency among the miners.

Compressed air escaping from the exhausts of drills or pumps has a well-defined cooling effect on underground air, but the compressed air escaping from air hose as blowers is likely to increase rather than decrease surrounding air temperature. Compressed air leaving the compressor frequently has a temperature of several hundred degrees F., and if released from open air hose as a blower in the upper part of a mine, where rock and air temperatures are cool, its temperature will frequently be higher than that of the surrounding air. Many determinations of the temperature of compressed air at the end of hose blowers in deep workings of hot mines showed that the temperature of this air was within a few degrees of that of the surrounding mine air, the feeling of coolness from the blowers being due to low humidity and high velocity of the compressed air and not to actual low temperature.

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

ANIMAL HEAT AND HEAT FROM LIGHTS AND MACHINERY.

Like the effect of firing of explosives, the cumulative effect of lights and breathing of men and animals on increase of mine-air temperature is ordinarily negligible, yet in confined, poorly ventilated places the effect is marked. A carbide light consumes somewhat less than one-half cubic foot of oxygen per hour, or about half the oxygen consumed by a man working with fair industry.

The aggregate heat from electric motors and machinery used underground is negligible. Locally it may be important especially in underground electrical stations, which, in general, are poorly ventilated and may have air temperature 8 to 10 or more degrees above that of the surrounding rock or the surrounding mine air.

Frequently workers in such confined places, when temperatures are high and the air generally vitiated, are subject to headache and dizziness, and occasionally have been known to be prostrated.

HEATED AIR FROM ADJOINING MINES.

Coal-mine practice generally recognizes the danger of ventilating one mine through another, but metal-mine practice commends intermine ventilation. Besides the dangers during mine fires, the practice is poor if underground temperatures are considered. Air will rarely be delivered from one mine to another until it has assumed essentially the rock temperature of the first, and probably also a high humidity and an addition of CO_2. Many a mine receives from its neighbor air at temperatures above 70° F., frequently over 80° F., and even as high as 90° F. and all the men in the mine are compelled to breathe this warm air, with an inevitable loss of working efficiency.

CONDITIONS AFFECTING RELATIVE HUMIDITY OF MINE AIR.

RELATIVE HUMIDITY OF SURFACE AIR.

In shallow mines, the relative humidity of the surface air may closely affect that of the underground air, particularly if the air velocity is high, although humidity changes quickly at low temperatures. In deep mines, especially where there is moisture, visible or invisible, in the surrounding wall of the intake air course, and at depths of 2,000 feet or more below the surface, air rarely leaves the intake air course with a relative humidity less than 70 per cent, irrespective of the humidity of the surface air. This is true even when the intake-air velocity approaches 1,000 linear feet a minute, and only rarely is the relative humidity of the air as low as 85 per cent

Generated on 2024-09-28 18:09 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

a few hundred feet from the intake air course. In a downcast shaft only 600 feet deep, which delivered about 50,000 cubic feet a minute, with surface humidity rarely above 50 per cent and frequently as low as 15 per cent, the relative humidity of the air in summer at the 600-foot level at the shaft was invariably above 85 per cent and frequently above 90 per cent. The shaft was essentially dry, no water being visible, and the increase of humidity was due chiefly to the reduction of temperature from 80° to 100° at the surface to about 60° at the 600-foot level.

In a deep downcast shaft, no water visible, the humidity assumed a winter constant of about 73 per cent and a summer constant of about 83 per cent, at the 2,200-foot level, when the air velocity was about 800 linear feet a minute. The constancy of the relative humidity of the swiftly moving air at the 2,200-foot level in this downcast shaft was remarkable. On one day the surface relative humidity was 58 per cent and on the next day 34 per cent, yet on both days relative humidity at the 2,200-foot station was 70 per cent. The increase of relative humidity from the surface to the 2,200-foot level was 1.64 per cent for 100 feet of air travel at 800 feet a minute and attendant increase of temperature was 0.66° F. to 100 feet of travel.

In general, mine air with a relative humidity of less than 70° is rare in metal mines, even in downcast shafts or intake air tunnels 1,000 feet or more underground, and this is true irrespective of the relative humidity of the surface air. In general, decrease of the relative humidity underground can be obtained only through rapid increase of the dry-bulb temperature.

MOISTURE CONTENT OF WORKINGS—QUANTITY OF AIR, VELOCITY, AND TEMPERATURE.

When the initial temperature of air is comparatively low and the relative humidity fairly high (the usual condition at point of discharge from the intake air courses described), if the rock temperature is approximately equal to the air temperature, the relative humidity will remain high and will increase rapidly if the workings are moist. If the rock temperature is lower than that of the intake air, the relative humidity will rapidly increase. If rock temperature is higher than the initial air temperature, the relative humidity will probably drop temporarily, especially if little or no visible moisture is present, and, unless surrounding walls and floor are very dry, it will soon increase. The rate of this increase will depend on the amount of moisture present in the walls and from drippers, on the air velocity and other factors, and it will vary from a fraction of 1 per cent to 2.3 per cent or more for each 100 feet of travel. When the temperature of the air has approximately reached that of the

Generated on 2024-09-28 18:21 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

surrounding rock and the relative humidity is 85 per cent or less, there will in general be a rapid increase of relative humidity, the rate of increase amounting to as high as 10 per cent for each 100 feet of travel when velocity is low (less than 100 linear feet a minute) and the surrounding walls and floor are damp. This latter condition illustrates what happens in nearly all metal mines when air leaves the main air courses to enter working places. In an area adjacent to mine fires and having abnormally high rock temperatures, but not actually taking air from the fires, the relative humidity may be very low because of the extremely high dry-bulb temperature, this being true irrespective of the velocity of the air.

Out of more than 1,000 readings of relative humidity in underground places in metal mines, chiefly in the western part of the United States and largely in dry climates and in mines rated dry, fewer than 10 per cent of the readings showed a relative humidity less than 80 per cent, and nearly all of these were in places close to intake air courses or where large volumes of compressed air were released in confined places or were ventilated by fan and tubing with attendant high temperature. Fully 95 per cent of all working faces at breast of stopes, crosscuts, drifts, raises, and winzes had a relative humidity higher than 90 per cent.

Air that has traveled through many hundred feet of deep workings, particularly if those workings include stopes and manways, will almost invariably have high temperature and a high relative humidity; on its return toward the surface this air generally has to pass through workings with lower rock temperatures, and in consequence there is in many places a rapid reduction of air temperature and a resulting deposition of moisture. When this moisture is deposited in a timbered stope, drift, or crosscut it tends to cause rapid decay of timber in spite of the timber being continually saturated with moisture and the air velocity being fairly high (1,000 linear feet or more a minute). Here is one of many reasons why upper workings should not be ventilated by air that has coursed through warmer, damp workings. When the hot, almost saturated, return air from lower workings of deep mines approaches the lower rock temperatures near the surface in return air shafts air temperature is rapidly reduced and moisture is deposited; this water falling freely in shafts has a tendency to reduce the air flow toward the surface. Frequently in shafts dependent on natural ventilation the falling of condensed water actually reverses the direction of air flow, converting upcast into downcast shafts.

SMALL FAN UNITS AND TUBING.

When mine air is forced by small fan through dry galvanized-iron or canvas tubing at high velocities (2,000 to 6,000 or more linear feet a

Generated on 2024-09-28 18:06 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

minute) there is a rapid increase of temperature and a corresponding decrease of relative humidity. In forcing air through 300 linear feet of 10-inch canvas tubing at rate of 4,800 linear feet a minute the relative humidity decreased 15 per cent at discharge end of the pipe, or about 5 per cent for each 100 feet of travel. With a short length of 16-inch galvanized-iron tubing having two 45° elbows and one 90° elbow, and with an air velocity over 6,000 linear feet a minute the dry-bulb temperature increased very rapidly (11⅔° F. for 100 feet of travel), but the relative humidity also rapidly decreased (31⅔ per cent for each 100 feet of travel). With a short length of dry canvas tubing, also 16 inches in diameter and having two 45° and one 90° elbows, the temperature increase at velocity of 6,700 feet a minute was 5¼°, and the relative humidity decrease was 13.7 per cent for 100 feet of travel. When, however, a spray of about 12 gallons an hour of water about 12° F. cooler than the surrounding (initial) air was introduced into this air at the fan intake no change occurred in dry-bulb temperature of discharged air over that of fintake air, and relative humidity increased only about 7 per cent for 100 feet of travel.

When air nearly saturated with moisture and at high temperature is forced by a fan through canvas tubing the temperature may decrease and the humidity increase, even when velocity is as high as 5,000 linear feet, provided considerable water at a lower temperature than that of entering air drips upon the canvas tubing for considerable distances. Such conditions are likely to cause deposition of condensed water within the pipe, and provision for draining the pipe must be made. This condensation is due to the cooling effect of the falling water and the lowered moisture-carrying capacity of the cooled air.

In a long crosscut, 2,300 feet from circulating air, a small electrically driven fan took return air, at 82° F. and 98 per cent relative humidity, from the top of a raise from the lower workings of a hot mine and forced it through 2,200 linear feet of 16-inch canvas tubing at a rate of 4,200 linear feet a minute, measured at the discharge end. Dropping water with a temperature of 72° to 75° F. fell on the canvas tubing at various points, and the air temperature within the tube was reduced from 82° at the entrance to 79° at the discharge end, and the relative humidity was raised to 100 per cent. So much water was deposited in the pipe that drainage had to be provided. In this place the workers seemed able to give efficient service and to work steadily and with apparent comfort in air at a temperature of 79° F., and 100 per cent relative humidity, the velocity at the working places being about 1,000 linear feet a minute, yet before the canvas pipe was put up and ventilation depended wholly on compressed-air blowers, new men had to be hired several times weekly and efficiency was low. The placing of this ventilation equipment reduced the cost of driving this place nearly 50 per cent, greatly increased progress, and

Generated on 2024-09-28 18:14 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

reduced the turnover of the working force from several hundred per cent a month to practically nothing.

UNDERGROUND WATER.

Underground water, especially in the form of "drippers," definitely influences the relative humidity and the temperature of mine air. At the end of a canvas pipe about 50 feet from the face of a crosscut, air with 71 per cent relative humidity emerged at a velocity of about 2,000 linear feet a minute; for 15 to 20 feet from the end of the pipe this swiftly moving air passed through a copious flow of water from drippers in the back, and its relative humidity rose to 91 per cent. Many similar readings have been taken showing how rapid is the increase of humidity of air passing through drippers even when the velocity of the air is rather high. Where air is stagnant, as at most working faces in metal mines, a comparatively small amount of water, especially if from drippers, will soon practically saturate the atmosphere, yet air 20 or 30 feet distant may have a relative humidity 20 per cent or more lower.

Cool water can be used to reduce the air temperature and also the relative humidity, although the immediate effect of use of cool water is to increase the relative humidity. In an intake shaft passing about 15,000 cubic feet of surface air a minute, a copious flow of water, as drippers, at about 50° F., insured air temperature of approximately 50° F. at the 1,200-foot level, whether the temperature of the surface air was 50° or 95° F.; both the wet-bulb and dry-bulb temperatures at the foot of the shaft were 50°, the relative humidity being 100 per cent, yet on a day when air was 85° F. and relative humidity 80 per cent at the surface, after this air had gone about 1,000 feet into a dry drift with high rock temperature, the dry-bulb temperature was 65° F., the wet-bulb 52° F., and the relative humidity 40 per cent. The cool "drippers" actually reduced the relative humidity of the intake air from 80 per cent at the surface to 40 per cent at a point 1,000 feet from the foot of the intake shaft.

CONDITIONS AFFECTING COMPOSITION OF MINE AIR.

COMPOSITION OF OUTSIDE AIR.

Outside dry air contains 20.93 per cent oxygen, 0.03 per cent CO_2, and 79.04 per cent nitrogen and other gases in negligible quantities. Occasionally in a metal-mining camp having smelters and numerous mines the surface air entering the mines may be slightly vitiated, possibly by 0.02 to 0.05 per cent SO_2, a small percentage of arsenical gases, or occasionally a little CO gas (possibly 0.01 to 0.03 per cent) from a near-by mine in which there is a mine fire or from a smoke-stack. Or the quantity of CO_2 may be slightly increased (0.05 to 0.10

Generated on 2024-09-28 18:07 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

per cent), or the oxygen decreased from 20.93 to about 20.80. In general any of these abnormal conditions are rare, occurring only during an unusually heavy fog or some unusual circumstance.

BREATHING OF MEN AND ANIMALS—HEAT AND FUMES FROM MINERS' LIGHTS.

The vitiating effect on mine air of the breath of men and other animals and the fumes from lights is variable and is negligible except in confined, poorly ventilated places. Analyses of mine air samples taken at new working faces (not in areas of decaying timber), where the air circulation is poor, although the mines are otherwise well ventilated, show in crosscuts and drifts a depletion of oxygen from 20.93 at the surface to 20.19 per cent and an increase of CO_2 from 0.03 at surface to 0.42 per cent; in raises a depletion of oxygen from 20.93 at surface to 20.54 per cent and an increase of CO_2 from 0.03 at surface to 0.22 per cent.

Analysis of air from new open stopes showed much less vitiation than in raises, drifts, and crosscuts, but there was much greater decrease of oxygen and increase of CO_2 in old stopes containing timber. Probably not all of the decrease of oxygen and increase of CO_2 at the faces of the raises, drifts, and crosscuts can be ascribed to the breathing of men and the fumes from candles and carbide lights, but in poorly ventilated places these factors undoubtedly affect the amounts of oxygen and carbon dioxide present. After two men with carbide lights had remained in a confined place in a raise for 45 minutes the oxygen depletion was 0.80 per cent and the increase of CO_2 was 0.64 per cent. No timber of any kind was in this place, and the men were afflicted with a headache after 30 minutes.

Fumes from a candle have not as much effect in decreasing oxygen and increasing CO_2 as has the breathing of a man; the effect of the miners' small carbide light is not as great as that of a candle, and the coal-miners' oil torch could not be used at 90 per cent of the working breasts in metal mines because of the rapid consumption of oxygen, the formation of CO_2, and the other noxious constituents of the smoke from the torch.

OXIDATION OR OXYGEN ABSORPTION BY ORE AND TIMBER.

In a large, fairly well ventilated metal mine where fans were used, about 450 men employed underground per shift and the volume of air supplied was about 50,000 cubic feet a minute, the oxygen content of the intake air was 20.93 per cent and that of the return air 20.20 per cent, showing a loss of oxygen of 0.73 per cent, or an oxygen consumption of approximately 22,000 cubic feet an hour. As the

Generated on 2024-09-28 18:12 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

maximum hourly oxygen consumption of the 450 men employed and their carbide lights could not possibly exceed 1,000 cubic feet, not more than 4 per cent of the oxygen depletion can be charged to breathing of the men and to their lamps in this fairly well ventilated mine. Similar data from a poorly ventilated metal mine, with natural ventilation, showed that the oxygen depletion possibly chargeable to the breathing of men and to lights was less than 6 per cent. Hence, there must be some much more important agent in oxygen consumption than men and lights, and that agent undoubtedly is decay of timber and oxidation of ore or minerals.

In the fairly well ventilated metal mine where the oxygen depletion was 0.73 per cent, the average of several analyses of return air showed CO_2 to have increased from 0.03 per cent in the intake air to 0.30½ per cent, or about 8,250 cubic feet an hour, and that the maximum amount of CO_2 produced by the breathing of men and by the burning of their lights was less than 1,300 cubic feet an hour. Therefore less than 15 per cent of the CO_2 production can be ascribed to men and lights in this mine; and in the poorly ventilated mine mentioned about 25 per cent of CO_2 produced could be charged to the men and their lights. Again, the increase must be ascribed chiefly to decomposition of timber and ore.

Almost every test in which samples of intake and return air were taken in metal mines showed the increase of CO_2 to be much less than it should have been if formation of CO_2 were the sole cause of oxygen loss; in other words, more oxygen was absorbed or combined than was consumed in forming CO_2. For instance, in the fairly well ventilated mine in which the oxygen consumption was 22,000 cubic feet per hour, the CO_2 increase was only 8,250 cubic feet an hour, but the oxygen necessary to form this amount of CO_2 was only 6,000 cubic feet. Therefore less than one-third of the total oxygen loss went into formation of CO_2 and over two-thirds of it must have been taken by the ore or timber, or both, or possibly by water.

High oxygen depletion is common in metal mines, in abandoned timbered workings, where the air is still, particularly if much moisture is present. In reworking abandoned back-filled timbered stopes or other workings, miners complain of "timber gas"; this, by analysis, shows a depletion of oxygen up to several per cent and the formation of CO_2 to about one-third of the amount of oxygen depletion. Air containing such small quantities of CO_2 as 0.3 per cent and showing an oxygen depletion of 1.5 per cent causes headache and discomfort to miners, especially if the air is still and the temperature is 75° F. or higher; possibly, however, the presence of objectionable odors or, if undetected, gases may have contributed.

Generated on 2024-09-28 18:11 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

Laboratory experiments of the Bureau of Mines at Pittsburgh, Pa., show that wood placed in air in sealed containers absorbs oxygen. This absorption is slow, or practically nonexistent when no moisture is present, which never happens in mines, and is much more rapid when the wood is finely divided, as shavings or sawdust, than when the wood is in solid compact form. When the timber is sterilized, little or no absorption of oxygen takes place. A series of laboratory tests are contemplated to get additional data on oxygen absorption, the formation of CO_2, and the temperature changes with various kinds of timber, ores, and minerals.

GASES FROM STRATA AND FROM MINE FIRES.

Harmful gases issue from the rocks in some regions, and if they are not adequately handled in mines they lessen the efficiency of workers and even cause loss of life. In some regions of eruptive or of carbonate rocks or ground carrying acid waters, CO_2 gas issues from the strata and at times almost excludes other constituents in the air of underground workings. With such condition a pressure system of ventilation is used to force the gases back into the crevices of the rocks. In other mines nitrogen issues from crevices, and in others sulphide of hydrogen issues from the mine waters. At an occasional metal mine the coal miners' enemy, methane or explosive gas, is found in recovering wet places where much timber is under mud and water. Methane also issues from small deposits of carbonaceous shale in the country rock at some metal mines; it may be found in other rocks, and under certain conditions it is formed from mine fires.

Gases from mine fires are of many kinds, depending on conditions. The most dangerous gas, especially from new fires or fires in fairly confined places, is CO, which, although most active in a new fire, may be expected at any time until the fire is completely extinguished. Amounts ranging from a few hundredths of 1 per cent to several per cent have been found in the gases from metal-mine fires. Various degrees of oxygen depletion are also encountered, as well as various percentages of CO_2, but, as already shown, the oxygen consumed from the air at the time of a fire does not all go into formation of CO_2. An average of 22 analyses of the gases from metal-mine fires, some from behind stoppings, some from return from more or less open fires, showed 3.73 per cent increase of CO_2, compared with 5.35 per cent depletion of oxygen, and some of the samples showed only 0.25 per cent oxygen and as much as 18.30 per cent CO_2.

As clearly indicated, methane (the coal miner's "gas") is a common constituent of the gases from metal-mine fires, and occasionally it has accumulated near fire bulkheads in explosive quantities (over

Generated on 2024-09-28 18:13 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

5 per cent); many samples of mine-fire gases show 1 per cent or more of methane. Sulphur dioxide is found in varying quantities up to one-fourth of 1 per cent in fires in metal mines with sulphide ores, and is to be expected in new fires in timbered sections when the fire has reached the incandescent stage. Hydrogen up to one-half of 1 per cent is frequently found in gases from metal-mine fires, and arsenical gases are found where enargite or other arsenical ores are exposed to fire.

Failure to take adequate action toward excluding fire fumes from other active workings of mines has caused many deaths and has greatly decreased the health and efficiency of workers, as minute quantities of CO, SO_2, and arsenical fumes lower vitality even if no permanent ill effects follow.

GASES FROM EXPLOSIVES.

In present-day metal mining, explosives generally used are 30, 35, or 40 per cent gelatin or ammonium-base dynamites, and general practice gives a half to 1 pound to the ton of ore extracted with as high as 5 or more pounds to the ton in hard rocks in confined places. One pound of ordinary 30 to 40 per cent gelatin dynamite will generate about one-half of a cubic foot of CO gas, with varying small quantities of other noxious gases, and although this volume may be negligible in a large stope where comparatively small quantities of explosive are used, or in any place where the air circulation is fairly good, in confined places, the situation is different. For example, a charge of 70 pounds of 40 per cent gelatin in 14 holes was fired electrically in a 5 by 7 crosscut in granite; a sample of the air at the breast three minutes after firing showed 1.04 per cent CO, 6.02 per cent CO_2, 18.23 per cent oxygen, 0.19 per cent CH_4, 0.48 per cent hydrogen, and 74.04 per cent nitrogen. Breathing such an atmosphere for five minutes would undoubtedly result in death.

Numerous air samples from muck piles where miners complained of headache averaged 0.25 per cent to 1 per cent CO_2, with oxygen depletion ranging from 0.50 per cent to as much as 2 per cent, and occasionally with oxides of nitrogen up to 0.01 per cent. No CO was obtained from air samples taken from muck piles, yet the gases from the piles may have contained some. The almost universal complaints of headache from muckers and the frequent attacks of nausea at faces of crosscuts or drifts where there is little or no air movement other than that afforded by compressed air, are ample evidence of the necessity for supplementing compressed-air blowers with some more efficient method of ventilation. This necessity is obvious without considering the numerous fatalities from gassing by explosive fumes in metal mines, such fatalities being rare in coal mines.

Generated on 2024-09-28 18:18 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

COMPRESSED AIR.

Generally in the best ventilated metal mines compressed air constitutes 10 to 20 per cent of the total volume of the air at working places, and in ordinary poorly ventilated metal mines from 50 to 80 per cent of the total air; in many parts of even the best ventilated metal mines, compressed air is the only available source of fresh air. In metal mines having rock temperatures of 75° F. or more, even when fairly elaborate ventilation systems are in operation (without, however, adequate distribution to the working faces), compressed air is in use in 50 to 75 per cent of all the working faces at practically all times. Compressed air, too, must be used freely in poorly ventilated mines with low rock temperatures if the air temperature is low, or even if it is high through oxidation of timber and ore.

Frequently underground workers complain that the compressed-air exhaust from pumps, hoists, and drills, causes headache, and nausea, yet many analyses of the exhaust from various kinds of machines fail to reveal any harmful constituents. Similarly, miners using compressed-air blowers complain of "bad" air and though several times prostrations have been ascribed to compressed air, analyses have shown no cause for trouble. It is possible, especially as regards the exhaust from drills or pumps, that oil spray may cause nausea, that through faulty conditions in compressors or receivers, harmful gases from volatilization of oil may enter the air, and that unless due precaution is taken, noxious gases from boilers may enter the intake of air compressors. In general, although analyses of compressed air show nothing harmful, due care should be taken to keep air receivers clean and temperatures low.

EFFECT OF DUST ON MINE AIR.

SILICEOUS DUST.

In ordinary metal mining much dust is generally raised, especially in the upper or drier workings. Some kinds of dust are more harmful to miners than others and siliceous dust is one of the worst in its ultimate effects, especially by inducing miners' consumption. The exact nature of the harmfulness of siliceous dust is not definitely established, though it is being studied in South Africa, England, and in the United States by the Bureau of Mines at Joplin, Butte, and in other mining regions, but the fact is well established that only very small particles, or those less than 1/2500 inch in largest dimension have a permanent ill effect on the lungs, and even these particles are not considered especially harmful unless they are sharp and prac-

Generated on 2024-09-28 18:15 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

tically insoluble.[1] Dust from free silica (quartz or chert) is supposed to be the most dangerous, but some well-authenticated cases cited by English authors would indicate that quartz dust is not especially harmful if mixed with certain other kinds of dust.

Dry drilling has been proved to be the most dangerous source of dust. The danger is especially great in drilling upper holes in quartz ore, as in driving raises, and somewhat less frequently in drifting and stoping. Inasmuch as the particles less than 1/2,500 inch largest diameter cause the worst trouble and as these particles remain suspended for several hours in dry, stagnant air, the dust danger in poorly ventilated places is obvious. Unfortunately all of the dry drilling in metal mines is done in the most poorly ventilated places, in raises and stopes. The dust menace at the faces of crosscuts and drifts is largely being lessened by use of Leyner drills, but even these drills when in poor repair provide a dust menace through formation of an air-water spray carrying fine particles of siliceous material from the drill hole. Therefore, even when wet drills are used, air circulation should be sufficient to remove quickly such air-water spray.

Other sources of danger from harmful dust are the mucking of dry ore, the raising of clouds of fine dust in blasting, and the throwing of fine dust into the air by timbermen. When dust raising can not be avoided, adequate air currents should be provided to remove the dust with minimum delay. Such preventive measures as use of wet drills, or water sprays, and shooting only when men are off shift, should be used where possible to supplement adequate ventilation.

DUST FROM SOLUBLE OXIDES OR CARBONATES.

The effect of the dust of soluble oxides or carbonates of lead, especially $PbCO_3$, is not so well understood as that of siliceous dust nor is the effect supposed to be as harmful. It is thought that the underground worker in soluble lead ores is injured by breathing the fine dust, by his skin absorbing the fine dust that settle on exposed parts of his body when covered with perspiration, especially in hot mines where a minimum amount of clothing is worn, and finally in wet mines, by absorbing through hands and feet. Quick removal of dust by adequate air currents would cool working places, allow most of the body to be covered, and prevent access of dust to the skin.

[1] Higgins, Edwin, Lanza, A. J., Laney, F. B., and Rice, G. S., Siliceous dust in relation to pulmonary disease in the Joplin district, Missouri. Bull. 132, Bureau of Mines, 1917. 116 pp. Lanza, A. J., and Higgins, Edwin, Pulmonary diseases in the Joplin district, Missouri, and its relation to rock dust in mines. Tech. Paper 105, Bureau of Mines. 1915. 48 pp. Harrington, Daniel. Miners' consumption in the mines in Butte, Mont. Tech. Paper 260, Bureau of Mines.

Generated on 2024-09-28 18:10 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

ARSENICAL DUST AND OTHER DUSTS.

Arsenical dust, dust from mercury sulphide, and dust from recovered mine-fire regions are more or less harmful. The prompt removal of these dusts by ventilating currents would greatly reduce dust hazards.

INFLUENCE OF VELOCITY ON MINE AIR.

AIR VELOCITY IN COOL MINES.

In cool mines (those with a dry-bulb temperature of 75° F. or less) a workman generally feels little or no discomfort even in still, nearly saturated air. However, when the oxygen is depleted 1 per cent or more (when the air contains 20 per cent or less oxygen), or when CO_2 is 0.30 or more, or when fumes from explosives "hang" in the muck pipe, or smoke hangs in the general air, headache, shortness of breath, and extreme readiness to perspiration are quickly noticed. Yet in such air, provided it is not too badly vitiated, a velocity of 25 to 50 linear feet a minute affords quick relief if the humidity is below 85 per cent, and a velocity of 100 linear feet or over gives much relief if the humidity is higher. It is the author's opinion that 25 feet a minute should be the minimum allowable air velocity in any working place underground. With temperatures less than 75°, velocities of 400 or 500 linear feet per minute are ample, though men can readily work in velocities as high as 1,000 linear feet a minute even when temperatures are much lower than can be obtained at the faces in ordinary metal mines.

VELOCITY AT VARIOUS TEMPERATURES.

As indicated above, where air temperatures are 75° or less comparatively sluggish currents (approximately 25 linear feet a minute) of pure air are generally satisfactory, and even when air is somewhat vitiated, velocity of 50 to 100 linear feet a minute affords relief. Where temperatures are between 75° and 95° F., especially if the relative humidity is high, still air is likely to cause excessive perspiration in the performance of even slight manual work, possibly headache and nausea, frequently mental dullness, and usually a rise of bodily temperature. In this air a slight oxygen depletion (1 per cent or even less) or a slight increase of CO_2 (0.25 to 0.50 per cent) will readily be manifest; yet give such air a velocity of 100 linear feet a minute or more, and the relief is immediate and definite.

With temperatures of 80° to 95° F. stagnant air is oppressive even if pure and the relative humidity low. Depletion of oxygen as small as 0.50 per cent, or increase of CO_2 under 0.25 per cent, will quickly

Generated on 2024-09-28 18:04 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

depress the worker, increase his perspiration, raise his bodily temperature, and lower his blood pressure. However, a velocity higher than 400 linear feet a minute gives relief, and little or no depression is felt even though the humidity is high.

With temperatures of 90° to 95° F., in stagnant air at low humidity, the effects of minute quantities of impurities are quickly manifest; yet, even air of this high temperature is endurable at a velocity of 500 linear feet a minute or more. When the air temperature is less than 95° F. and the relative humidity as high as 98 per cent, high-velocity air, such as furnished by small fans and canvas tubing, make conditions relatively comfortable for the worker as long as he remains in the current.

While aiding in some experiments by the Bureau of Mines and the United States Public Health Service, on the effect of high temperatures on the human system, the author remained at rest 60 minutes in a place where the temperature was 97½° F., the relative humidity 90 per cent, and the air had no movement. In the 60 minutes perspiration was profuse, yet bodily temperature rose to 101.8° F., or fever temperature. A few feet away issued from the end of a canvas pipe air at 90° F. and 75 per cent relative humidity at a velocity of 2,300 linear feet a minute. After the author had stood in such air 15 minutes his bodily temperature fell from 101.8° F. to 100.9° F., and his pulse fell from 136 to 120, and his blood pressure rose from 98 to 106 systolic and from 68 to 82 diastolic, indicating the quick relief afforded by swiftly moving air even at a temperature of 90° F.

When air temperatures rise above blood heat (98° F.) practically the only means to prevent discomfort or lowered efficiency is rapid circulation of air, together with as low humidity as is possible. In the heat experiments mentioned, a man whose bodily temperature had risen to 100.2° F. after remaining 45 minutes at rest in still air at 97½° F. and 90 per cent relative humidity walked 200 feet along a level and carried a short ladder back to his resting place; this slight effort in the hot, humid, stagnant, atmosphere forced his bodily temperature to 102.6° F., indicating the probable effect on bodily temperature of trying to do hard work in temperatures higher than 100° F.

VELOCITY AT VARIOUS HUMIDITIES.

A humidity of less than 60 per cent is rare underground, even in dry climates or in dry, shallow mines, though in the vicinity of a mine fire, when the rock is abnormally heated, lower humidities are occasionally found. Until dry-bulb temperature approaches 75° F., a relative humidity practically up to saturation causes little or no

Generated on 2024-09-28 18:07 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

discomfort, even though the air is still, unless the air is depleted of oxygen or is charged with comparatively large quantities of CO, CO_2, or other noxious gases. When such air is given a velocity of 25 linear feet or more, work can be done normally. With the relative humidity 85 per cent or more and the temperature 75° to 85°, stagnant air, even when pure, is oppressive, and its oppressiveness is greatly intensified with even a small decrease in oxygen supply or increase of CO_2. However, where comparatively pure air of the above sort is given a velocity of 100 linear feet a minute, a miner feels no appreciable discomfort even when working fairly hard. Similarly, stagnant air, regardless of purity and humidity, is oppressive at temperatures of 90° to 95° F., and the oppressiveness increases as the air approaches saturation. With a velocity of 400 linear feet or more a minute, such air is not particularly oppressive and with velocities of 1,000 or more linear feet a minute the effect is pleasant, particularly if the relative humidity is not more than 95 per cent.

When temperatures reach 100° F. or higher, and the relative humidity is close to 100 per cent, even comparatively high velocities give little relief. On the other hand, air with temperatures as high as 110° F., but with a relative humidity of 85 per cent or less, although distinctly oppressive when still, is readily endurable when it has a velocity of 1,000 linear feet or more a minute. Hence, if adequate movement is supplied, the relative humidity is not a deciding factor until temperatures exceed 100° F. and humidity approaches 100 per cent.

VELOCITY WITH VARIOUS GASES PRESENT.

As already stated, pure still air at a temperature less than 75° F. is usually comfortable, even when its humidity approaches saturation; however, when still air is nearly saturated at a temperature of 70° to 75° F., quantities of CO_2 as small as 0.25 per cent, with slight oxygen depletion, are quickly shown underground by physiologic effects such as increased perspiration or slight headache. When temperatures are less than 70° F., considerably higher percentages of CO_2 or greater oxygen depletion are not very noticeable, even in still air, and it is thought that several per cent of CO_2 may be present in low-temperature air without noticeable effect, provided the velocity is several hundred feet a minute and the oxygen content remains above 12 per cent. However, even in low-temperature air, more than 0.03 per cent CO will cause headache unless the air has high velocity, and 0.1 per cent CO or more will probably result in unconsciousness of the worker in a comparatively short time even if

Generated on 2024-09-28 18:09 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

the air velocity is high. The author has spent several hours continuously in air whose CO content was approximately 0.03 per cent, with temperature about 70° F. and relative humidity 95 per cent, but probably because of the air velocity of several hundred feet a minute he experienced no perceptible ill effects, not even the usual headache from CO.

When temperatures are above 75° F. minute quantities of CO, CO_2, or oxygen depletion quickly cause shortness of breath, headache, dizziness, or nausea if the air is stagnant, and especially if it is also nearly saturated with moisture. Yet high-temperature air with less than 1 per cent CO_2, less than 1 per cent oxygen depletion, and less than 0.1 per cent CO is comfortable at a velocity of several hundred feet a minute.

Although the effects of underground air are greatly influenced by temperature, humidity, and gases, yet air velocity is probably of greater importance than all of the other agencies combined, with the possible exception of the removal of poisonous gases. In general, workers can be comfortable, healthful, and efficient if the air in which they work is circulating, even though that air is comparatively hot, humid, and to a considerable extent vitiated. The effect of even slight air movement was noticed by the author in a western mine in which the workers in a stope with stagnant air at 79° F. and relative humidity 86 per cent were accustomed several times daily to climb to the level above to "cool off" in air which, although actually 3° hotter and with 5 per cent greater relative humidity than the air in the stope, moved at a rate of 150 linear feet a minute.

NECESSITY FOR EFFICIENT CONTROL OF VENTILATION.

In the foregoing pages the discussion has related chiefly to the elements that affect underground air, with comparatively little consideration of the economic factors that might control provision for good or efficient ventilation, the possible costs, or the advantages to be derived. The two main considerations are the humanitarian, or the welfare and health of workers, and the financial, or the cost in dollars and cents.

Efficient air circulation prevents loss of life and impairment of the health of workers in metal mines. There are numerous instances of lives lost or nearly lost and of temporary and permanent sickness due to gases from surrounding strata or from fumes of explosives, which could have been removed by adequate air circulation. Many cases of such acute diseases as pneumonia and bronchitis and of such chronic diseases as miners' consumption and lead poisoning could be prevented by providing air circulation to remove harmful dusts and

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

to reduce high temperatures and humidity and by protecting the workers from undue exposure to surface weather conditions. Removal from working places of hot, humid, stagnant air would prevent dizziness, nausea, anemia, high blood pressure and bodily temperature, and possibly the death of miners.

As regards the cost in dollars and cents, adequate and controlled ventilation would be justified by decrease of time lost by underground workers, by saving in compressed air used for blowers, and by better control of mine fires. As an illustration of the saving of time of workers, the use of small fan units with canvas or galvanized pipe in many mines has reduced time lost after firing of shots in drifts and crosscuts from 30 or 60 minutes to 5 or 10 minutes. These fan units, by continuous removal of fumes from muck piles while shovelers worked, have prevented loss of workers' time through headache, nausea, and other physical distress. With moving air currents at working faces, workers may save as much as 50 to 70 per cent of the time of total shift which is now lost in seeking relief from hot, humid, or vitiated air. The efficiency of workers in places so depleted of oxygen that a candle will not burn could readily be increased 25 per cent or more if the places were supplied with pure circulating air.

Compressed air was being used for ventilation in three out of every four work faces of the deep metal mines investigated which employed large numbers of men. The average compressed-air consumption was over 100 cubic feet a minute for each blower, or more than enough to run the largest drill, but with the difference that the drill works (hence consumes compressed air) only about 20 per cent of the time, whereas the blowers were used fully 90 per cent of the shift. In these mines with large numbers of compressed-air blowers running, although large air-compressing plants were in operation, the drillers were compelled to work with compressed-air pressure less than 50 pounds per square inch (frequently much less), hence were able to accomplish little in comparison with what they could have done if the pressure were 75 pounds or more.

At time of mine fires in mines with poorly controlled ventilation, such as those not supplied with fans and doors, much property loss and frequently loss of life has resulted because of inability to control the air supply and the fire fumes. Lives and much property have been saved by having surface fans in fire-proof houses, and so arranged that the air currents may be quickly reversed, by having doors and fans in place when emergencies occurred. In mines with well-defined splits and with doors absolutely separating the air circulation of each split from that of every other split mine fires and fire fumes are readily, quickly, safely, and cheaply isolated.

Generated on 2024-09-28 18:08 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

METHODS OF PROVIDING EFFICIENT VENTILATION FOR METAL MINES.

Efficient ventilation of metal mines consists in supplying at all times such volumes of circulating air at all working places as will enable the miner to work in comfort at maximum physical capacity without endangering his health. Most of the better practice in present-day metal-mine ventilation consists in supplying volumes of air through the drifts and a few manways, with little or no attempt to conduct moving or fresh air to the faces or breasts where men work. This is comparable, especially in hot mines, to the conditions that would exist in a large office building on a hot day if no fans were used and all windows to the exterior were closed and room occupants were dependent on such air circulation as might happen to enter rooms through the elevator shafts, corridors, or halls.

Methods of providing efficient underground air circulation may be divided into inducing main underground air currents, transmitting these main currents through the underground workings, and, by far the most important, distributing air currents to the working places.

INDUCING MAIN UNDERGROUND AIR CURRENTS.

The first division includes natural ventilation, furnace ventilation, and fan ventilation. In natural ventilation air flow is caused by differences in the surface elevation of mine openings, or it may be caused or greatly influenced by the difference in the temperature of the rock underground and the temperature of outside air. When surface air temperature and underground rock or water temperatures differ widely, considerable differences in pressure occur, due to difference in weight of hot as against cool air, and currents set up may be ample for ventilation. Where air temperature outside and rock or water temperatures inside are approximately equal, there is little or no difference in pressure and air circulation ceases or is sluggish. Hence, in general, hot mines dependent on natural ventilation have sluggish currents or no circulation in summer, and occasionally their air currents reverse direction. In spring and fall and on cool nights in summer mines that have cool rock temperatures and depend on natural ventilation have either sluggish air currents or a practically daily reversal of direction of air currents; there are intervening periods during early evening and before noon when practically no air moves underground. However, mines using natural ventilation and having a copious supply of falling water in the downcast shaft are generally free from the above difficulties due to fluctuation of outside temperature. The worst disadvantage from placing absolute dependence on natural ventilation is the inability of the management

Generated on 2024-09-28 18:10 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

to control air currents during underground fires. For this reason alone all mines should be equipped with fans and other mechanical ventilating devices.

Furnace ventilation, which is merely a modification of natural ventilation, is somewhat dangerous because of the use of fire underground, is almost as inelastic as natural ventilation, and costs almost as much if not quite as much as adequate fan ventilation.

Fan ventilation is by far the most efficient of the three methods and is being adapted by progressive present-day metal-mining companies. The most up-to-date installations have multi-blade, high-speed fans of steel, generally on the surface in concrete or otherwise fireproof housing, and arranged so as to reverse underground currents in a few minutes' time through the closing and opening of doors. These fans may be steam driven, but most of them are electrically driven, the smaller ones being direct connected and the larger ones having belt or rope drive. Alternating or direct current may be used, and all possible provision should be taken for fireproofing and for providing extra bearings, motors, and belts for insuring quick repairs in case of a breakdown. For very important fans two quickly interchangeable methods of fan drive, such as steam and electricity, should be provided.

In some metal mines in which gas issues from the strata, as well as in some mines having fires, air is supplied under pressure behind air locks, and this pressure is maintained in such manner as to force the gases away from the places where miners are working. The pressure system of ventilation is also used in some well-ventilated mines in order to distribute air currents to working places. In general, however, metal-mine fans operate as exhaust units, this being true of many mines having fires or in which gases issue from the strata. Both pressure and exhaust systems can be used to advantage, provided suitable precautions are taken to meet peculiar local conditions, and either may be a failure unless judgment is used in planning the ventilation system.

TRANSMITTING MAIN CURRENTS THROUGH MAIN WORKINGS.

Many considerations enter into the transmitting of main air currents through main workings. Each mine should have its own main intake and its own main return; in other words, each mine should be ventilated independently, and although this seems to be a drastic statement, innumerable examples may be cited illustrating the dangers of intermine ventilation not only to health and life, but also to efficiency and to property. If possible, main intake and return air courses should be used as air ways only and should be kept as free from obstructions as possible and upcast shafts should be kept free

Generated on 2024-09-28 18:06 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

of falling waters. When haulage ways, whether shafts or tunnels, must be used as main air courses, cages, skips, locomotives, and cars should be kept out of these main air courses except when in actual use. Shafts and tunnels used as main air courses should have as great area as possible, and tunnels should have few square turns. Compared with a rough lining a smooth lining for shafts carrying air at a high velocity will allow, in general, the delivery of at least 30 to 50 per cent more air with the same consumption of power. Main air courses should be equipped with fireproof doors in fireproof doorjambs; the doors should be hung so as to close flush against the outside of the doorjamb, and not to enter the doorjamb, in order to prevent sticking from any settlement of ground. These main doors, and all underground doors, should be arranged to close automatically and to stay closed, by latch or other means, even during a reversal of air currents, as at the time of a mine fire. Doors that open automatically or that remain closed because of air pressure only are dangerous, especially at the time of a mine fire, when men are in a panic, or when air currents may quickly reverse. Also, such doors in ordinary practice are likely to be left open, with resulting impairment of ventilation. Doors used for deflecting air currents rather than for fire purposes should also close and latch automatically and, in general, in order to avoid leakage, they should be placed in pairs with an air lock between. The size of the air lock (distance between doors) depends on whether the lock must hold a trip or train of cars, in which case the doors should be so placed as to allow reasonable clearance for maximum length train, or, if only men pass through, the latch should be operable from either side of the door, and the doors may be placed only 10 feet apart or even less. Firedoors should be so placed in drifts leading from shafts used as main air courses that such shafts may be wholly isolated from other mine workings by closing these doors, and, if possible, these doors should be so arranged that they may be closed by some device at the surface.

DISTRIBUTION OF AIR CURRENTS TO WORKING FACES.

The most important and generally the most neglected feature in metal-mine ventilation is the distribution of air to the working faces. In one of the best ventilated mines of a large mining district the author found that out of 158 working places he visited at only 75 was the circulation of air strong enough to be detected by the slightest movement of a candle flame, but men were working in all the places visited. Of the 71 places, 29 gave only a very faint movement of the flame (air velocity less than 25 linear feet a minute), so that only 42 out of 158 working places had fair or good movement of air, and of these 42 only 24 were at the working face

Generated on 2024-09-28 18:19 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

or breast. In other words, only about 25 per cent of the working places of a metal mine rated as well ventilated had enough air movement to give comfortable working conditions, and nearly half of these comfortable working places were in the main air courses. In this supposedly well-ventilated mine less than 10 per cent of all raises can be said to have had adequate ventilation, only 30 per cent of the stopes had any perceptible air movement, and about 50 per cent of the working places in drifts and crosscuts had fair or good air movement, only about 20 per cent of these well-ventilated places being at faces or breasts. Such conditions show the necessity for more efficient distribution of air, for the mine in question is ventilated by fan, the total delivery of air exceeds the amount supplied most coal mines, and the general ventilation is greatly in advance of that in all other mines of the district.

Prevention of leakage is one of the main problems of air distribution in metal mines. Doors on main air courses should be constructed to permit only the minimum leakage, and where pressure is high, air locks should be provided, as has been indicated. Openings from main air courses to crosscuts, drifts, manways, and chutes should be efficiently sealed by tight doors, board, or other brattices to exclude air from places where men do not work, to insure a maximum quantity of air reaching the working places, and to exclude from the fresh air any heated or otherwise vitiated air coming from abandoned workings.

Another important feature in the distribution of air to working faces is the splitting of the main intake air currents into several parts, so that each such air split will have a velocity less than 1,000 linear feet a minute, will be confined to a certain well-defined split, preferably one with not over 50 men (or 100 as a maximum), will not mix with any other split except in returning to the surface, and will be returned to the surface as quickly as possible, preferably before it is unduly vitiated with smoke and fumes, or reaches a temperature higher than 80° F. Where possible, drifts and raises should be driven in pairs with break-throughs at intervals of about 50 or 100 feet, to allow air circulation, and the faces of all such break-throughs except the last one should be closed, as in coal-mining practice. When drifts or crosscuts are driven singly, circulation may be maintained up to distances of 500 feet by the use of line brattices, as in coal mining, if the openings are more than 6 feet wide or high. For narrow drifts or crosscuts, or for wide ones over 500 feet from circulating air, small fans with galvanized-iron or canvas tubing are used to advantage. In sinking shafts or winzes, small fans may be used either by tightly sealing one shaft compartment from the other or by using a tight board box or galvanized iron or canvas.

Generated on 2024-09-28 18:09 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

If canvas pipe is used, it should be protected by a board box, and when small fans are used with tubing, whether in shafts, drifts, or raises, the fan should be used as a blower, as this gives the workers at the face the benefit of the high velocity of the air issuing from the tube, although the use of exhaust fans will probably clear the face of fumes from explosives more quickly than will the blower.

To ventilate raises is easy if they have three compartments, for then the middle compartment can be used as ore chute and the other compartments as upcast and downcast. A small water spray falling in the downcast compartment causes faster air circulation. In two-compartment raises, in which one compartment is the ore chute and hence is frequently closed, air circulation is greatly facilitated by driving the raises in pairs and making break-throughs every 50 or 100 feet vertically. Small fan units with canvas pipe are used to advantage if the pipe is inclosed in a box to protect it from falling rock.

Ventilation of stopes is the most difficult problem. One of the most vital points is the restriction of the area of the opening, for it is obviously impracticable to have a velocity of several hundred feet a minute when the area is larger than 100 square feet. In these large open stopes fumes give little trouble, and cool water sprays or small fan-canvas tubing units satisfactorily reduce temperature. To deflect air from main air courses on levels into stopes, doors or canvas curtains may be used across the levels, and the manways to the stopes should be as close as possible to stope breasts and as free as possible from obstructions, and occasionally a raise or manway free of platforms or timbers which obstruct air flow should lead into large stopes. Frequently air from manways can be readily deflected into stopes by the use of a trapdoor or canvas. Much inefficient circulation of air at the faces of stopes is due to failure to provide such simple devices as deflecting doors. In ventilating all kinds of blind ends in metal mines, canvas tubing can be used to great advantage because of small first cost, ease of placing, flexibility in turning angles, and efficiency in delivering of air. Canvas pipe has the advantage over galvanized-iron pipe, as a "firing" length of 25 or 50 feet may be taken down in about five minutes before blasting and replaced just about as quickly after blasting. The coolness and comfort afforded the worker at the face by the rapidly moving air do much toward influencing him, if fair-minded, to do a full day's work.

DIRECTION AND CONTROL OF VENTILATION IN METAL MINES.

Inasmuch as little or no provision for ventilation is made in metal mining until the mine becomes fairly extensive, the problem,

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

when finally attacked, is more difficult than in coal mining, where provision for ventilation must be made with the opening and the development of the mine. For this reason metal-mine ventilation problems should be placed in the hands of a competent engineer. As very little efficient ventilation work has been done in metal mines the engineer should have had experience in coal mines and should also be thoroughly conversant with general metal-mine practice. Large metal-mining companies operating several mines should permanently employ a competent engineer to be in complete charge of ventilation, and accountable only to the higher officials, as is the chief geologist, the chief mining engineer, or the chief mechanical engineer. This plan is necessary because of the importance of ventilation, and because ventilation will be neglected unless it is taken completely out of the jurisdiction of lesser mine officials, such as foremen or shift bosses, who in general firmly believe that air distribution is a useless fad and impracticable in metal mines.

Each metal mine should have its ventilation equipment and extensions in charge of a certain specified man, or men, who should periodically inspect conditions and see that ventilation extensions keep pace with mining development. If these duties will not justify holding a man full time he can be given additional duties. Those in charge of ventilation should be allowed to keep in touch with plans for future underground development, with a view to planning for the ventilation needs of the new workings, and they should make and be given authority to enforce adequate rules and regulations as to control of fans, doors, air courses, stoppings, and as to fire-fighting plans and equipment.

If the mine has openings to adjoining mines of different ownership, especially if there is interchange of air, the man in charge of ventilation should represent his mine in forming inter-company rules and regulations as to doors, air courses, and stoppings used in common, and as to procedure in case of mine fire. If the adjoining companies should fail to agree to such regulation, the State inspection department should be asked to intervene and force an agreement. Where two or more adjoining mines of the same company are ventilated through one another the ventilation of all mines so connected and ventilated should be under control of one man, who should have authority to enforce any orders he issues on ventilation. Interventilation of mines is dangerous and inefficient at best and has resulted in much loss of life in both coal and metal mines. A lack of coordination of authority as to exits and air movement in mines connected underground is more than inefficient; it is criminal.

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

COST OF VENTILATION OF METAL MINES AND SAVING TO BE EFFECTED.

The cost of adequately ventilating metal mines is somewhat difficult to give as data are available from very few mines. At coal mines the cost is generally less than 3 cents a ton of coal produced, and in two metal mines which were efficiently ventilated the total cost was less than 5 cents a ton hoisted, including interest, depreciation, maintenance, and the cost of all leakage and general use of compressed air after the theoretical compressed-air consumption of mining machines had been deducted from the total volume of air compressed. The installation cost includes that of the fan, with housing, which should not exceed $15,000, and may well be less than $10,000 for a comparatively large mine, the placing of doors, regulators, and booster fans underground, and possibly the repairing of shafts and drifts to allow of air circulation. Maintenance cost includes wages paid those in charge of ventilation, together with labor and material for repairs, upkeep, and extensions. In general, it is safe to conclude that adequate ventilation may be maintained in a large mine for less than 5 cents a ton of ore produced, and in small mines the cost may be as high as 10 cents a ton.

Compared with possible savings, the costs are negligible. The advantages derived at the time of a mine fire from properly designed and maintained ventilation systems, mechanically controlled, justify by themselves a cost of 10 cents a ton. This has been frequently demonstrated, especially in recent metal-mine fires in the West, both in mines where fans and doors were in use and in mines where they were lacking. In a hot mine the saving of compressed air alone more than compensates for the entire cost of maintaining adequate ventilation. In one mine with average working temperature over 90° F. before installation of fans and doors, the temperature was reduced to less than 75° F. by ventilating. At this mine compressed air cost 10 cents a ton before installation of the ventilation system chiefly because of use of compressed-air blowers, whereas the combined cost of both compressed air and ventilation was less than 10 cents a ton after the ventilation system had become effective, for the compressed-air consumption was reduced fully 50 per cent. This reduction of expense should excite no surprise, for the average cost of compressing 1,000 cubic feet of air to 90 pounds pressure is about 3 cents, whereas the average cost of supplying 1,000 cubic feet of air by fan ventilation underground is about 0.03 cent.

When mines are hot and the air at working places is vitiated or stagnant, compressed-air blowers are used excessively, each blower consuming over 100 cubic feet of air a minute and generally in use at least 420 out of the 480 minutes of the shift, whereas a drill by

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

actual time record is in use on an average of 100 minutes out of the 480-minute shift, a stoper using 50 to 75 cubic feet of air a minute and the larger types using less than 100 cubic feet a minute. Each blower will use at least six times as much compressed air as the average stoper in an eight-hour shift and at least four times as much as the average large-sized hammer or piston drill. Therefore, the average blower consumes at least 42,000 cubic feet of compressed air daily, which at 3 cents a thousand costs $1.26; whereas the cost of supplying the same amount of air by ordinary ventilation at 0.03 cent a thousand would be but 12.6 cents, the excess cost of ventilation by each blower being $1.134 a day.

In a comparatively hot metal mine, where ventilation was much better than the average, 75 out of 158 working places visited were using compressed-air blowers at a cost of 75 × $1.134, or $85.05 a day, more than it would have cost to have given these 75 places adequate ventilation by ordinary methods. Moreover, the 75 places using blowers were not adequately ventilated, the men were unable to work in comfort, and the use of so much compressed air reduced the pressure to less than 50 pounds a square inch, and throughout the mine the efficiency of the air was lowered about 50 per cent.

From 30 to 60 per cent of the possible obtainable efficiency is lost when underground workers are compelled to work in places with hot, stagnant, vitiated air, and this condition establishes low standards that spread to other more favorable working places and make the raising of the standard difficult, even after the ventilation is improved. However, the installing of efficient ventilation in several hot, smoky mines has actually increased the output of the muckers 50 per cent.

The economic loss to the metal-mining industry from miners' consumption is enormous, not only in health and lives but also in dollars and cents. In some very important and populous mining localities the death rate from consumption among miners is 10 to 15 times as great as the average death rate for that disease throughout the country. It is a conservative estimate that for inefficiency of workers afflicted with miners' consumption the metal mines of the United States pay an annual toll of several millions of dollars and metal miners lose an almost equal amount in lost time. Yet this disease, caused chiefly by breathing large quantities of extremely fine, hard, insoluble dust in metal mines, is wholly preventable, and one of the greatest preventive measures is an adequate supply of air currents at working faces to remove the fine dust particles and also the hot, humid, stagnant air which promotes disease. Economic losses caused by bronchitis, pneumonia, lead poisoning, and gassing by explosives, although not as great as those due to miner's consumption, are serious for the same reasons. These also can be largely prevented by adequate ventilation.

Generated on 2024-09-28 18:05 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

Wide-awake metal-mine operators are taking measures to "clean house" in order to forestall the enormous charges which must be met when sickness insurance and compensation laws sweep the country during the next few years as accident compensation laws have done during the past decade. There must be a change of attitude toward air distribution in metal mines and the recognition that not only is adquate, efficient metal-mine ventilation feasible, but that it is as essential to the financial well-being of the metal-mine owner as it is to the health and comfort of the underground worker.

PUBLICATIONS ON MINE GASES AND MINE VENTILATION.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted and to insure equitable distribution, applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution, as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

BULLETIN 75. Rules and regulations for metal mines, by W. R. Ingalls and others. 1915. 296 pp., 1 fig.

BULLETIN 105. Black damp in mines, by G. A. Burrell, I. W. Robertson, and G. G. Oberfell. 1916. 92 pp.

BULLETIN 132. Siliceous dust in relation to pulmonary disease among miners in the Joplin district, Missouri, by Edwin Higgins, A. J. Lanza, F. B. Laney, and G. S. Rice. 1917. 116 pp., 16 pls., 6 figs.

BULLETIN 188. Fire at the North Butte mine, June 8, 1917, by Daniel Harrington. (In press.)

TECHNICAL PAPER 105. Pulmonary disease in the Joplin district, Missouri, and its relation to rock dust in the mines, by A. J. Lanza and Edwin Higgins. 1915. 48 pp., 5 pls., 4 figs.

TECHNICAL PAPER 119. The limits of inflammability of mixtures of methane and air, by G. A. Burrell and G. G. Oberfell. 1915. 30 pp., 4 figs.

TECHNICAL PAPER 122. Effects of oxygen deficiency on small animals and men, by G. A. Burrell and G. G. Oberfell. 1915. 12 pp.

TECHNICAL PAPER 134. Explosibility of gases from mine fires, by G. A. Burrell and G. G. Oberfell. 1916. 31 pp. 1 fig.

Generated on 2024-09-28 18:12 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY

TECHNICAL PAPER 150. Limits of complete inflammability of mixtures of mine gases and of industrial gases with air, by G. A. Burrell and A. W. Gauger. 1917. 13 pp., 2 figs.

TECHNICAL PAPER 174. Suggestions for the safe operation of gasoline engines in mines, by R. H. Kudlich and Edwin Higgins. 1917. 19 pp., 3 figs.

TECHNICAL PAPER 224. Metal-mine accidents in the United States during the calendar year 1917, with supplemental labor and accident tables for the years 1911 to 1917, inclusive, by A. H. Fay. 1919. 80 pp.

TECHNICAL PAPER 252. Metal-mine accidents in the United States during the calendar year 1918, with supplemental labor and accident tables for the years 1911 to 1918, inclusive, by A. H. Fay. 1920. 113 pp.

MINERS' CIRCULAR 10. Mine fires and how to fight them, by J. W. Paul. 1912. 14 pp.

MINERS' CIRCULAR 13. Safety in tunneling, by D. W. Brunton and J. A. Davis. 1913. 19 pp.

MINERS' CIRCULAR 16. Hints on coal-mine ventilation, by J. J. Rutledge. 1914. 22 pp.

Generated on 2024-09-28 18:09 GMT / https://hdl.handle.net/2027/njp.32101054990468
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from PRINCETON UNIVERSITY